Adsorption on a Corrugated Substrate

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Using an effective Hamiltonian approach we study adsorption of a fluid on a two dimensional, periodically corrugated substrate. The substrate is translationally invariant in one direction. The wetting phenomenon consists of a growth of the thickness of the adsorbed film from a microscopic to the macroscopic value. It is a surface phase transition connected to the nonanalyticity of the surface contribution to the free-energy of the system. At the bulk liquid-gas coexistence the wetting temperature depends on the geometry of the substrate in the case of the first-order wetting transition. The critical wetting temperature remains unchanged by the geometry of the substrate. In both cases, critical and the first-order wetting, the wetting transition can be preceded by the first-order thin-thick transition, called a filling transition. This phase transition is connected to the nonanalyticity of the line contribution to the free-energy of the system. We analyse the shape of the liquid-gas interface and its change at the filling transition in the case of the short-ranged interactions. We discuss the influence of such properties of the substrate like the corrugation amplitude, the corrugation period, the curvature of the substrate, and the nonanalyticities of its shape on the adsorption phenomena within the framework of the mean-field theory, and next, we discuss fluctuation effects which can smooth out the filling transition. The phase diagram of the adsorption is obtained for some particular shapes of the substrate and the mean-field critical exponents are evaluated. We give a detailed description of the filling and wetting transition for the saw shaped substrate, sinusoidally corrugated substrate, and nonanalytical, purely convex and purely concave substrate. The filling transition, if it exists, occurs provided the corrugation of the substrate exceeds a specific, critical value. We analyse the square-gradient approximation of the effective Hamiltonian suitable for substrates with small gradients of the corrugation, and the drum-head model which does not restrict the roughness of the substrate. The line tension between coexisting thin and thick films is evaluated in the vicinity of the filling critical point. The line tension vanishes at this point. We analyse its singularity at the filling critical temperature.